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(54) **Continuous ink jet printhead and method of rotating ink drops**

(57) A continuous ink jet apparatus is provided. The apparatus includes a nozzle (16) array. A drop forming mechanism (22) is positioned relative to the nozzle array and is operable in a first state to form ink drops having a first volume travelling along a path and in a second state to form ink drops having a second volume travelling along the path. A system (32) applies force to the ink drops travelling along the path with the force being applied in a direction such that the ink drops having the first volume diverge from the path and at least one of the ink drops having the first volume and the second volume are rotated relative to the length dimension. At least a portion (48) of the system is configured to rotate the ink drops.

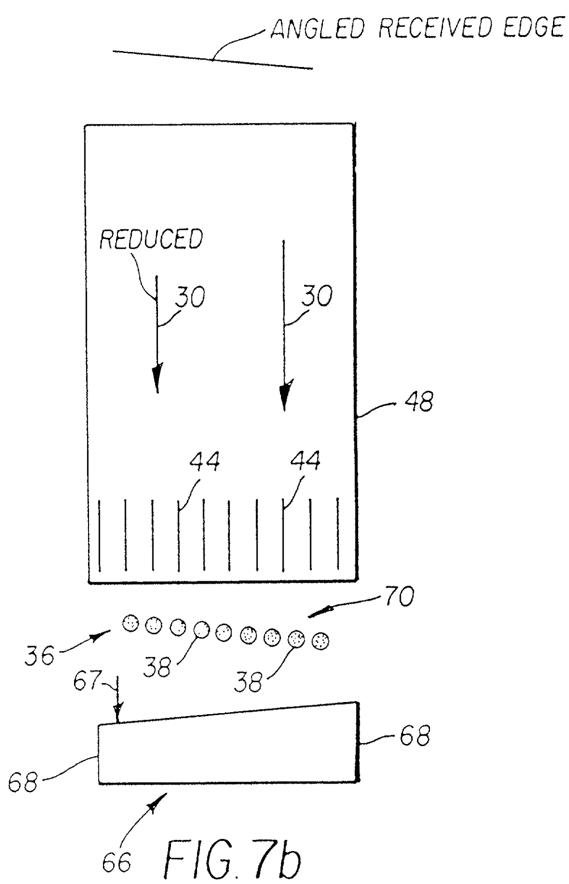

FIG. 7b

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Description

[0001] This invention relates generally to the design and fabrication of inkjet printheads, and in particular to printheads configured to uniformly translate the position of printed ink drops on a receiver without altering the position of the printhead with respect to the receiver.

[0002] Traditionally, digitally controlled inkjet printing capability is accomplished by one of two technologies. The first technology, commonly referred to as "drop-on-demand", ejects ink drops from nozzles formed in a printhead only when an ink drop is desired to impinge on a receiver. The second technology, commonly referred to as "continuous", ejects ink drops from nozzles formed in a printhead continuously with ink drops being captured by a gutter when ink drops are not desired to impinge on a receiver.

[0003] Referring to Fig. 1, a printhead 120 typically includes an approximately linear row of nozzles 122 which define printhead length 124 (measured in a direction along the nozzle row). Printhead 120 is scanned across a stationary receiver 126 in a fast scan direction 128. After fast scan 128 is complete, receiver 126 is moved in a receiver motion direction 130 relative to printhead 120. Typically, receiver motion 130 is orthogonal or substantially orthogonal to fast scan direction 128 and receiver 126 is moved in receiver motion 130 rather than displacing printhead 120 in a slow scan direction 132. Printhead 120 is subsequently scanned again in fast scan direction 128 with nozzles 122 having been physically displaced with respect to receiver 126 by an incremental amount (shown schematically so as to be easily compared to printhead length 124). The overall result is displacement of printhead 120 is in slow scan direction 132. Typically, displacement of printhead 120 with respect to receiver 126 in slow scan direction 132 is a fraction of nozzle to nozzle spacing 134. Typically, slow scan direction 132 is also orthogonal or substantially orthogonal to fast scan direction 128. Alternatively, printhead 120 can be physically stepped in slow scan direction 132 in order to physically displace printhead 120 with respect to receiver 126. Receiver 126 can also be moved in slow scan direction 132 in order to accomplish displacement of printhead 120 with respect to receiver 126. In either situation, either printhead 120 or receiver 126 is moved. Typically, the above-described motions are controlled by a controller 134. Many commercially available desktop printers (drop-on-demand printers, etc.) operate in this manner.

[0004] In continuous inkjet printers, receiver 126 is typically moved in fast scan direction 128 rather than printhead 120 because of the size and complexity of printhead 120. In many cases, printhead length 124 is pagewide and extends across the entire width of receiver 126 with fast scan direction 128 of receiver 126 being perpendicular to printhead length 124. This type of printhead and/or printer is commonly referred to as a "pagewidth" printhead/printer. Alternatively, printhead 120 can be scanned in fast scan direction 128, then stepped in slow scan direction 132 before printhead 120 scanned again in fast scan direction 128.

[0005] In some continuous printing applications, it is desirable to move printhead 120 in slow scan direction 132 in order to translate the pattern of printed ink drops (with respect to receiver 126) produced by nozzles 122. For example, in several conventional pagewidth printers, printhead 120 is translated or dithered a small distance from side to side in a direction parallel to its length (slow scan direction 132). This motion can be used to compensate for irregularities in nozzle to nozzle spacing 134 of printhead 120. Typical nozzle to nozzle spacing 134 is a multiple of the desired distance between printed dots. As such, printhead 120 can be displaced slightly along its length and fast scan 128 is repeated one or more times in order to print all desired dots. Typically, translated printed drop patterns are created by translating printhead 120 in slow scan direction 132 with respect to receiver 126. However, receiver 126 can be translated or displaced in slow scan direction 132 while printhead 120 remains stationary in slow scan direction 132.

[0006] Translation of the printhead in the slow scan direction is very precise. As such, commercially available mechanical devices that perform this task increase overall printer costs, are complex, and are prone to failure. Additionally, commercially available printheads often perform poorly when translated or dithered rapidly due to fluid acceleration along the length of the printhead. This is particularly true for pagewidth printheads because pagewidth printheads have extremely long fluid channels, typically distributed over the entire length of the printhead. Rapidly displacing the printhead intensifies the adverse affects of the fluid acceleration. As such, there is a need for an improved printhead translatable along its length (typically, in the slow scan direction relative to the receiver).

[0007] Additionally, it is advantageous to adjust the location of ink drop patterns printed on a receiver in the slow-scan direction in order to improve image quality. In this regard, displacing, dithering, or translating the printhead by an integral spacing relative to nozzle to nozzle spacing (the distance between nozzles) allows selected nozzles to print different data, thereby reducing image artifacts. The printhead motion (translation) needs to occur quickly in order to accomplish this. Typically, this motion is completed in a time much shorter in duration than the time required to scan in the fast scan direction. Again, currently available mechanical devices that accomplish this motion increase system cost and complexity. As such, there is a need for an improved printhead capable of adjusting the location of ink drop pattern printed on a receiver.

[0008] It is also advantageous to adjust the location of ink drop patterns printed on a receiver so as to slightly change the angle of the printhead relative to the fast scan direction in order to suppress image artifacts. This situation typically arises, for example, when the angle of the receiver changes while passing under the printhead. In many of these situations, changing the angle of the printhead relative to the fast scan direction needs to occur rapidly in order to prevent printed ink drops from misregistering (being printed on the wrong location) on the receiver. Again, currently available mechanical devices for moving the printhead at an angle relative to the fast scan direction add expense and complexity. Additionally, these devices can interfere with printhead performance during printhead motion in the fast scan direction due to the additional weight of the devices. As such, there is a need for an improved printhead capable of changing the angle of drops printed from a row of nozzles.

[0009] An object of the present invention is to provide an improved printhead translatable along its length.

[0010] Another object of the present invention is to provide an improved printhead rapidly translatable along its length that accurately and rapidly produces displaced printed drops in a direction parallel to the length of the printhead without interfering with the performance of the printhead.

[0011] Another object of the present invention is to provide an improved printhead capable of rapidly rotating the pattern of printed ink drops through an angle with respect to the receiver.

[0012] Yet another object of the present invention is to produce a displaced pattern of ink drops printed on a receiver without having to displace the receiver or the printhead.

[0013] Yet another object of the present invention is to provide an improved printhead having reduced cost and increased reliability.

[0014] According to a feature of the present invention, a continuous ink jet printing apparatus includes a nozzle array with portions of the nozzle array defining a length dimension. A drop forming mechanism is positioned relative to the nozzle array. The drop forming mechanism is operable in a first state to form ink drops having a first volume travelling along a path and in a second state to form ink drops having a second volume travelling along the path. A system applies force to the ink drops travelling along the path. The force is applied in a direction such that the ink drops having the first volume diverge from the path with the ink drops having the first volume being rotated relative to each other along the length dimension.

[0015] According to another feature of the present invention, a method of rotating ink drops ejected from a continuous ink jet printhead includes forming ink drops having a first volume travelling along a path; forming ink drops having a second volume travelling along the path; causing the ink drops having the first volume to diverge from the path; and causing the ink drops having the first volume to be rotated relative to each other.

[0016] According to another feature of the present invention, a method of translating ink drops includes forming a first ink drop travelling along a path; forming a second ink drop travelling along the path; causing the first ink drop to diverge from the path; and causing the second ink drop to diverge from the path rotated relative to the first ink drop.

[0017] According to another feature of the present invention, a continuous ink jet printing apparatus includes a nozzle array. A drop forming mechanism is positioned relative to the nozzle array. The drop forming mechanism is operable to form a first ink drop travelling along a path and a second ink drop travelling along the path. A system applies force to the first and second ink drops travelling along the path. The force is applied in a direction such that the first and second ink drops diverge from the path. At least a portion of the system is configured to reduce the force along the path such that the second ink drop is rotated relative to the first ink drop as the second ink drop diverges from the path.

Fig. 1 shows a prior art inkjet printhead being scanned over a receiver;

Figs. 2a-2c show schematic cross-sectional views of an apparatus incorporating the present invention;

Figs. 3a-3c show a schematic top view of a portion of the apparatus of Fig. 2a and resulting printed ink drop patterns;

Figs. 4a and 4b show schematic top views of the portion of the apparatus of Figs. 3a-3c made in accordance with the present invention and resulting printed ink drop patterns;

Fig. 4c shows a row of printed ink drops produced by the apparatus of Figs. 4a and 4b;

Fig. 4d shows a row of printed ink drops produced by the apparatus of Figs. 4a and 4b;

Figs. 5a and 5b show schematic top views of alternative embodiments of the apparatus of Figs. 4a and 4b;

Fig. 6a shows a schematic top view of an alternative embodiment of the apparatus of Figs. 4a and 4b translated between a first position and an offset second position;

Fig. 6b shows a time history of the pattern of ink drops printed on a receiver for the printhead of Fig. 6a;

Fig. 7a shows a schematic top view and a cross-sectional view of an alternative embodiment of the apparatus of Figs. 4a and 4b with the resulting pattern of printed ink drops;

Fig. 7b shows a schematic top view and a cross-sectional view of the embodiment of Fig. 7a with the resulting pattern of printed ink drops;

Fig. 7c shows a schematic top view and a cross-sectional view of an alternative embodiment of Fig. 7c with the resulting pattern of printed ink drops;

Fig. 7d shows a schematic top view and a cross-sectional view of an alternative deflector system of Fig. 7a with the resulting pattern of printed ink drops;

Fig. 7e shows a cross-sectional view of an alternative embodiment of Fig. 7d;

Fig. 7f shows a schematic top view, a side view, and an end cross-sectional view of an alternative embodiment of Fig. 7a with the resulting pattern of printed ink drops; and

Fig. 7g shows a control surface for the embodiment shown in Fig. 7f.

[0018] The present description will be directed in particular to elements forming part of, or cooperating more directly with, apparatus in accordance with the present invention. It is to be understood that elements not specifically shown or described may take various forms well known to those skilled in the art.

[0019] Referring to Figs. 2a-2c, an apparatus 10 incorporating the present invention is schematically shown. Although apparatus 10 is illustrated schematically and not to scale for the sake of clarity, one of ordinary skill in the art will be able to readily determine the specific size and interconnections of the elements of the preferred embodiment. Pressurized ink 12 from an ink supply 14 is ejected through nozzles 16 of printhead 18 creating filaments of working fluid 20. Typically, nozzles 16 are formed in a membrane of printhead 18 overlying an ink cavity formed in printhead 18. Ink drop forming mechanism 22 (for example, a heater, piezoelectric actuator, etc.) is selectively activated at various frequencies causing filaments of working fluid 20 to break up into a stream of selected ink drops (one of 26 and 28) and non-selected ink drops (the other of 26 and 28) with each ink drop 26, 28 having a volume and a mass. The volume and mass of each ink drop 26, 28 depends on the frequency of activation of ink drop forming mechanism 22 by a controller 24.

[0020] A force 30 from ink drop deflector system 32 interacts with ink drop stream 25 deflecting (through angle D) ink drops 26, 28 depending on each drops volume and mass. Accordingly, force 30 can be adjusted to permit selected ink drops 26 (large volume drops) to strike a receiver W while non-selected ink drops 28 (small volume drops) are deflected, shown generally by deflection angle D, into a gutter 34 and recycled for subsequent use. Alternatively, apparatus 10 can be configured to allow selected ink drops 28 (small volume drops) to strike receiver W while non-selected ink drops 26 (large volume drops) strike gutter 34. System 32 can includes a positive pressure source or a negative pressure source. Force 30 is typically positioned at an angle relative to ink drop stream 25 and can be a positive or negative gas flow. The gas can be air, nitrogen, etc.

[0021] Referring to Figs. 3a-3c, a schematic top view of deflection system 32 and a resulting pattern 36 of printed ink drops 38 printed on a receiver is shown. Fiducial lines 40 represent displacement of printed drops in slow scan direction from reference points. In Fig. 3a, the reference points are edges 42 of system 32 with at least a portion of system 32 being positioned substantially parallel to nozzle row and the direction of force 30 being perpendicular to ink drops ejected from nozzle 16. Alternatively, force 30 can be altered in a first altered direction (as shown in Fig. 3b) such that printed drops are displaced with respect to fiducial lines 42 (downward in Fig. 3b). Force 30 can also be altered in a second altered direction (as shown in Fig. 3c) such that printed drops are displaced with respect to fiducial lines 42 (upward in Fig. 3c).

[0022] Figs. 4a and 4b show a first embodiment implementing the present invention. A portion 48 of system 32 is configured with a plurality of control vanes 44 used to control the direction of force 30 in a first direction (aligned with edges 42 of system 32 as shown in Fig. 4a) and in a second direction (angled from edges 42 of system 32 as shown in Fig. 4b). Alignment of control vanes 44 in Fig. 4a is perpendicular to nozzle row 122 while alignment of control vanes 44 in Fig. 4b can vary but is generally not perpendicular. The resulting printed drops 38 in Fig. 4b are displaced along the direction of the nozzle row (in slow scan direction 132) due to alteration of the direction of force 30 caused by angling of control vanes 44. Control vanes 44 can be fabricated using known MEMS technology and techniques. Additionally control vanes 44 can be made from various known materials. For example, control vanes 44 can be made from small metallic pieces which are rotated about a common support point 46 located at an end of each control vane. A known controller can be used to angle control vanes 44 at an appropriate time with an appropriate amount of angle.

[0023] By printing with subsequent scans of printhead 120 in fast scan direction 128, with each scan having an altered direction of force 30, resulting patterns 36 of printed ink drops 38 with displaced drops 43 and non-displaced drops 45, as shown in Figs. 4c and 4d, can be accomplished without having to mechanically displace printhead or receiver. In Fig. 4c, ink drops 38 are displaced from one scan to another by one half the distance between nozzles. In Fig. 4d, ink drops 38 are displaced by a amount greater than one half the distance between nozzles. Typically, a useful displacement includes a multiple of a simple fraction of the distance between nozzles. For example, in Fig. 4d, ink drop displacement is two thirds the distance between nozzles such that subsequently displaced scans can "fill in" the scan line with additional evenly spaced ink drops. Useful displacement can also include a multiple of a simple fraction greater than one (for example, 5/4, etc.) and/or a multiple of a simple fraction less than one half (for example, 1/6, etc.) depending on the criteria for a particular situation. In these examples, the number of scans required to fill in a line with drops of regular spacing would be 4 and 6, respectively, as can be appreciated by one skilled in the inkjet printing art.

[0024] An inexpensive manufacturing method for making vanes 44 is electroforming a metal such as nickel, nickel-iron alloy, or the alloy known as permalloy, etc. into vane-shaped openings defined by an xray patterning of a thick polymer film, a technique known in the art of microfabrication as LIGA. Vanes 44 may be attached together by an electroformed bridge 47, sufficiently thin to flex so as to allow vanes 44 to be angled, at their top and bottom surfaces as shown at the top side of vanes 44 by dotted lines 47 in Fig. 4a and 4b, so that all vanes 44 move together. The vanes 44 are made from a magnetic material such as permalloy, vanes 44 can be angled by application of a magnetic field from a magnet with poles spaced the same as vanes 44 and positioned above system portion 48 or at the sides of system portion 48 or bridge 47 near the front of system portion 48. Alternatively, vanes 44 can be contacted mechanically by an arm from a servo motor. The positions of the drops, either before or after printing, can be easily monitored with a CCD camera and vanes can be then adjusted by programming a controller in a feedback loop to alter the magnet field (or to actuate the servo motor) until the desired drop position is achieved. As can be appreciated by one skilled in mechanical design, many additional ways of fabricating vanes and actuating their motion are possible. For example, vanes 44 can be fabricated by injection molding vanes 44 from a conductive plastic material and controlling their position by electrostatic attraction to an additionally provided set of interleaved vanes in system portion 48, or by fabricating vanes 44 from a piezo material and electrifying that material to angle vanes 44.

[0025] Fig. 5a and 5b show a second and a third embodiment of the present invention. Again, control vanes 44 redirect force 30 in order to alter the position of printed ink drops. In these embodiments, at least a portion 48 of system 32 is aligned during one scan and angled with respect to fast scan direction during a subsequent scan. In Fig. 5a, portion 48 has a rectangular shape and is rotated (shown at 50) using any known devices and techniques relative to nozzle row 122. As portion 48 is rotated, the distance from ends of portion 48 relative to nozzles gradually changes causing displacement of printed ink drops. In Fig. 5b, portion 48 has a trapezoidal shape such that the distance from the ends of portion 48 to nozzle row remains constant along an end of portion 48. In practice, it has been discovered that the amount of deflection of printed ink drops is not very sensitive to (or dependent on) the distance of the ink drops from portion 48. For example, a change in the distance of ink drops from portion 48 of 1 mm results in a change in drop deflection of less than 20 microns after the drop has traversed interaction distance L of portion 48 (a vertical direction dimension of 1mm in Fig. 2a). As such, trapezoidal shapes are required only when extremely accurate and very uniform ink drop translations are desired.

[0026] Portion 48 can be rotated by commercially available rotational servo motors based on signals provided from controller 134. Controller 134 can use a look-up table to determine the signal required for a given desired displacement of the printed drops or the positions of the drops, either before or after printing. This can be easily monitored with a CCD camera and the degree of rotation can be then adjusted by programming controller 134 in a feedback loop to alter signal to a servo motor until the desired drop position is achieved. If, as in Fig. 5b, system portion 48 is to be held parallel to nozzle row 122, a servo motor can be used to rotate the system portion 48 by rotating sidewalls 49, 51 of system portion 48, but side walls 49, 51 of system portion 48 should be free to slide mechanically on top and bottom surfaces of system portion 48. In this example, right end (as shown in Fig. 5b) of side walls 49, 51 should be located in a fixed position, and the top and bottom surfaces should be made to extend beyond sidewalls 49, 51 so that when sidewalls 49, 51 are angled and slide along the top and bottom airtube surfaces, sidewalls 49, 51 do not pass over the edges of the top and bottom surfaces of system portion 48.

[0027] Referring to Fig. 6a, another embodiment of the present invention is shown. This embodiment is especially appropriate when rapid or periodic translation of printed drops in the slow scan direction is desired. In Fig. 6a, system portion 48 having control vanes 44 is displaced in alternating first (aligned relative to fiducial lines 42) and second (offset relative to fiducial lines 42) directions 52, 54 (in a slow scan direction, etc.). This creates flow patterns in force 30 that translate printed ink drops 38 in directions corresponding to first and second directions. Fig. 6b shows lines 56 of ink drops 38 printed on a receiver 58 moving in a receiver scan direction 60 with the ink drops being ejected simultaneously from nozzles 16 in nozzle row 122 (of Fig. 2b). The line of printed ink drops is displaced in proportion to the speed of displacement of system portion 48 in slow scan direction. Displacement distance of printed ink drop corresponds to translation distance of system portion 48. However, translation of system portion 48 is such that system portion 48 does not overshoot nozzles 16 positioned at ends of nozzle row 62. As such, force 30 of system portion 48 does not miss ink drops ejected from nozzles 16 positioned at ends of nozzle row 122.

[0028] System portion 48 may be translated as shown in Fig. 6b by commercially available linear servo motors based on signals provided from controller 134. Controller can use a look-up table to determine the signals required for a given desired displacement of the printed drops or the positions of the drops, either before or after printing. This can be easily monitored with a CCD camera and the degree of translation can be then adjusted by programming controller 134 in a feedback loop to alter signal to the servo motor until the desired drop position is achieved.

[0029] The embodiments described above disclose apparatus and methods for translating a pattern of ink drops ejected from a nozzle row in a direction parallel to nozzle row 120 without moving printhead 120. It is also useful in inkjet printing to have precise control of ink drop line rotation of ink drops printed from a nozzle row with respect to an edge of a receiver. Controlling ink drop line rotation helps to correct for receiver alignment problems (relative to a printhead, etc.) and prevent image artifacts. Alignment problems include a receiver initially misaligned, becoming slightly misaligned during a fast scan or while being moved after a fast scan of a printhead, etc. Roll fed printers are particularly susceptible to slight angular misalignment of paper as it slides or moves over the printing region. Alignment problems are significant in the printing art, as the human eye is extremely sensitive to image artifacts arising from an angular rotation of rows of printed drops relative to an edge of a receiver.

[0030] Referring to Fig. 7a, a schematic top-view of system portion 48 and a pattern 36 of ink drops 38 printed on a receiver is shown. Typically, pattern 36 results when nozzles 16 in nozzle row 122 simultaneously eject printed drops. Printed drop pattern 36 is typically aligned perpendicularly to receiver edge 136 (shown in Fig. 1a) during printing. Receiver edges 136 can become misaligned (not aligned perpendicularly, angled, etc.). This can happen, for example, when there is a slight error in the direction of receiver motion which can occur in printers that periodically move the receiver (a roll-fed printers in which the receiver is unwound from a roll during printing, etc.).

[0031] Referring also to Fig. 7b, in order to compensate for the misalignment of a receiver edge, system portion 48 has been deformed mechanically from a rectangular cross-section 64 (Fig. 7a) to a trapezoidal cross-section 66. Deformation can be accomplished by applying a mechanical force 67 to system portion 48 with an elastic side member(s) 68. Deforming system portion 48 reduces flow of force 30 causing less deflection of ink drops. As shown in Fig. 7b, left side of system portion 48 has been deformed. As such, printed drops 38 on left side are deflected to a lesser degree (shown generally at 70) as force 30 is also reduced. The ink drop deflection reduction gradually decreases for drops ejected from nozzles positioned toward a right side of nozzle row because force 30 remains substantially constant (shown generally at 70) on right side of system portion 48. The resulting printed pattern 36 of ink drops is rotated through a slight angle. Alternatively, ink drop rotation can be from right to left. The exact amount and shape of deformation of system portion 48 can be selected such that the printed ink drops are precisely aligned to the misaligned or angled receiver. Typically, the exact deformation is calculated using computational modeling of force 30 as known to one of ordinary skill in the inkjet printing art. As such, rotational alignment of printed ink drops relative to a receiver edge is accomplished without rotating either the printhead or the receiver.

[0032] System portion 48 may be constructed of side members 69 which are shaped in the form of a bellows having corregations (shown in Fig. 7a) that is easily compressed when a downward force is applied. Such a force may be provided by planar magnetic coils 71 attached to the inside top of system portion 48 near the side to be compressed and positioned directly over a similar set of planar magnetic coils attached to the inside bottom of system portion 48. A current may be passed through both sets of coils from controller 134 to pull down the top surface of the airtube magnetically. Controller 48 can use a look-up table to determine the current required for a given desired displacement of printed drops 38 or the positions of the drops, either before or after printing. This can be easily monitored with a CCD camera and the degree of translation can be then adjusted by programming controller 134 in a feedback loop to alter the current until the desired drop position is achieved. Alternatively, a second bellows sidewall 73 can be positioned very near the first (dotted line in Fig. 7a), the open end between sidewalls 69 and 73 being sealed to air using a flexible material like latex, and a vacuum applied to the space between bellows sidewall 69, 73 to collapse the bellows and compress system portion 48.

[0033] Fig. 7c shows a second embodiment of the invention shown in Figs. 7a and 7b. In Fig. 7c, force 30 is reduced on left side of system portion 48 by changing the angle 72 between members of pairs of control vanes 44 so as to increase resistance to flow of force 30. Control vanes 44 can be constructed using known MEMS techniques from small metallic pieces which are rotated about a common support point 46. As flow of force 30 is reduced on left side of system portion 48, printed ink drops 38 corresponding to left side are deflected to a lesser degree than on right side. Alternatively, ink drop rotation can be from right to left. As such, the printed pattern 36 of drops is rotated through an angle without moving the printhead or the receiver.

[0034] Vanes 44 may be fabricated by injection molding each of vanes 44 from a conductive plastic material, the mold including a rod portion 45 running vertically through vane 44 and extending above the top and bottom of the vane, the location of the rod being shown at 45 in the top view of vanes 44 in Fig. 7c. Rod 45 is located away from vane center so that electrostatic forces to be described cause selected rotation of the vanes. Rods 45 of each vane 44 are cemented into locating holes in the top and bottom of system portion 48 to that vane 44 rotates on the rod 45 by twisting it. Each vane 44 is contacted electrically at the locating holes by a thin film conductor patterned on the top or bottom system portion 48. Controller 134 is programmed to apply a selectable control voltages to each vane 44 and to thereby control pairwise the angular positions of vanes 44 by electrostatic attraction. A typical control voltage pattern on the vanes 45 can be positive and negative voltages for vane positions shown in Fig. 7c. As can be appreciated by one skilled in electrostatics, electrostatic attractive forces occur for oppositely charged vanes whereas no forces occur pairwise between similarly charged vanes. Controller 134 can use a look-up table to determine the voltages required for a given desired angulation of vanes 44; or the positions of the drops, either before or after printing. This can be monitored with a CCD camera and the degree of angulation can be then adjusted by programming controller 134 in a feedback loop to alter magnitude of the voltages applied to vanes 44.

[0035] Figs. 7d and 7e show additional embodiments of the invention shown in Figs. 7a and 7b. In Figs. 7d and 7e force 30 is reduced by positioning a shaped restrictor 74 (rectangular in Fig. 7d, trapezoidal in Fig. 7e). Restrictor 74 increases resistance force 30 in proportion to its degree of penetration into the flow of force 30 and to its length along the direction of flow. Restrictor 74 can be a mechanically moved block, nominally positioned relative to system portion 48 (in a recessed area of portion 48, etc.) and moved down into the flow of force 30 when rotation of a printed drop pattern is desired. A top view of restrictor 74, shown in Fig. 7d, is preferably trapezoidal helping to further reduce flow of force 30. Additionally, a top view of restrictor 74, shown in Fig. 7e, is preferably rectangular so as not to reduce flow of force 30 too much. As flow of force 30 is reduced on left side of system portion 48, printed ink drops corresponding to left side are deflected to a lesser degree than on right side. Alternatively, rotation can be from right to left. As such, the printed pattern of drops is rotated through an angle without moving the printhead or the receiver.

[0036] Airflow restrictor 74 is conveniently made from an elastic membrane affixed at its edges to the top inner surface of system portion 48. A membrane of restrictor 74 may be inflated pneumatically by connecting it pneumatically to a narrow tube running along the top inner surface of system portion 48 and exiting system portion 48 through its top surface at a location chosen to prevent mechanical interference with system portion 48 supports or with a receiver. The narrow tube is connected to a pneumatic source through valves which can be opened and closed by controller 134. When inflated, the shape of restrictor 74 is determined by the air pressure and by the distance of the elastic membrane from any point on its surface that is affixed to the top inner surface of system portion 48. A membrane which is rectangular in top view and which is affixed to the inner top surface of system portion 48 only around its perimeter will inflate as shown in Fig. 7d. A restrictor 74 whose top view is trapezoidal will inflate as shown in Fig. 7e. Controller 134 can use a look-up table to determine the valve openings required for a given desired displacement of the printed drops; or the positions of the drops, either before or after printing. The degree of translation can be then adjusted by programming controller 134 in a feedback loop.

[0037] Figs. 7f and 7g show another embodiment of the invention shown in Figs. 7a and 7b. In Fig. 7f, flow of force 30 is reduced by positioning a control mechanism 76 such that control mechanism 76 interacts with force 30. Control mechanism 76 has at least one adjustable cantilever 78 (as shown in Fig. 7g). Each cantilever 78 can be individually extended (bent, pushed, etc.) into force 30 thereby restricting flow depending on the degree of penetration of each cantilever 78 and the length of control mechanism 76 along the direction of flow of force 30. Control mechanism 76 can be constructed using MEMS techniques well known to those skilled in the art. For example, control mechanism 76 can incorporate an electrical conductor and each cantilever 78 can be aluminum thin films patterned photolithographically into long, thin plates that are electrostatically attracted by application of a voltage to cantilevers 78. When no voltage is present, each cantilevers 78 can be designed to have internal stresses causing them to extend away from control mechanism 76. Alternatively, each cantilever 78 can be bimetallic strips which curl up when heated by an electric current passed through the strip or along its length. This is also well known to one of ordinary skill in the art. Typically, control mechanism 76 shown in Fig. 7d is rectangular as viewed from a top view. However, control mechanism 76 is not required to be rectangular as long as cantilevers 78 are individually controlled. As flow of force 30 is reduced on left side of system portion 48, printed ink drops corresponding to left side are deflected to a lesser degree than on right side. As such, the printed pattern of drops is rotated through an angle without moving the printhead or the receiver.

[0038] A voltage applied to a particular cantilever 78 will cause that cantilever 78 to move from a contracted to an extended state. To control airflow through system portion 48 in accordance with the present invention, the position of each cantilever 78 on control mechanism 76 is adjusted by applying a plurality of voltage signals from controller 134. The voltages being conveyed to control mechanism 76 through a plurality of electrical leads which may be fabricated on the inner top surface of system portion 48 which extend along the inner top surface and exit system portion 48 in order to connect to controller 134 through the top surface at a location chosen to prevent mechanical interference of the leads with system portion 48 supports or the receiver.

[0039] Due to the small size of cantilevers 78, there is a need to have very many of them to effectively control force 30. As such, there is a need to provide many, for example a hundred or more, electrical leads. Control mechanism 76 can be attached to these electrical leads within system portion 48 by techniques such as bump bonding, known in the art of semiconductor package fabrication. Controller 134 can use a look-up table to determine the values of the voltages required to achieve force 30 control sufficient to provide a desired displacement of the printed drops. Alternatively, the positions of the drops, either before or after printing, can be easily monitored with a CCD camera and the degree of rotation can be then adjusted by programming controller 134 in a feedback loop to alter the voltages applied to the cantilevers and hence the positions of the cantilevers until the desired drop position is achieved. It is possible to control the flow of force 30 in system portion 48 to a very high degree of accuracy due to the large number of voltage output from controller 134.

Claims

1. A continuous ink jet printing apparatus comprising:

   a nozzle (16) array;
   a drop forming mechanism (22) positioned relative to the nozzle array, the drop forming mechanism being operable to form a first ink drop travelling along a path and a second ink drop travelling along the path; and
   a system (32) which applies force to the first and second ink drops travelling along the path, the force being applied in a direction such that the first and second ink drops diverge from the path, at least a portion (48) of the system being configured to reduce the force along the path such that the second ink drop is rotated relative to the first ink drop as the second ink drop diverges from the path.

2. The apparatus according to Claim 1, portions of the nozzle array defining a length dimension, wherein the rotation of the second ink drop relative to the first ink drop is relative to the length dimension.

3. The apparatus according to Claim 1, the system portion having an outlet, the system portion being deformable between a first shape and a second shape, wherein the second shape reduces the force along at least a portion of the outlet.

4. The apparatus according to Claim 1, the system having an outlet and including a mechanism (76; 78; 74; 44; 67; 71) positioned in the system portion, the mechanism being moveable between a first position and a second position, wherein the force along at least a portion of the outlet is reduced as the mechanism portion moves from the first position to the second position.

5. The apparatus according to Claim 1, wherein the system portion includes at least one control vane (44).

6. The apparatus according to Claim 1, portions of the nozzle array defining a length dimension, wherein the system portion is positioned substantially perpendicular to the length dimension of the nozzle array.

7. The apparatus according to Claim 1, the drop forming mechanism being operable in a first state to form the first and second ink drops, the first and second ink drops having a first volume, wherein the drop forming mechanism is operable in a second state to form first and second ink drops having a second volume travelling along the path, the force being applied in a direction such that the first and second ink drops having the second volume remain travelling substantially along the path.

8. A method of translating ink drops comprising:

   forming a first ink drop travelling along a path;
   forming a second ink drop travelling along the path;
   causing the first ink drop to diverge from the path;
   causing the second ink drop to diverge from the path rotated relative to the first ink drop.

9. The method according to Claim 8, wherein causing the first ink drop to diverge from the path includes applying a force in a first direction along the path.

10. The method according to Claim 9, wherein causing the second ink drop to diverge from the path rotated relative to the first ink drop includes reducing the force applied along at least a portion of the path.

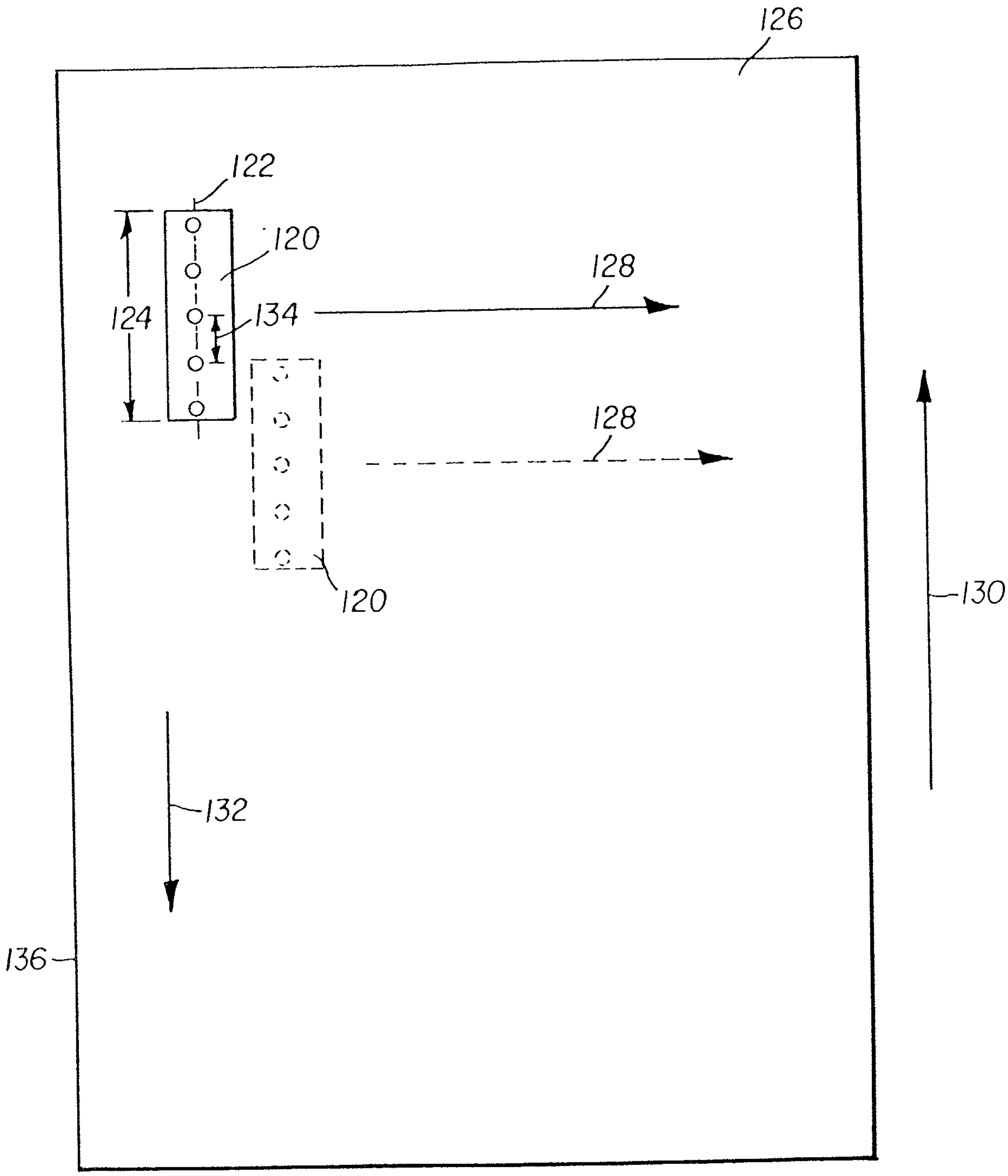

FIG. 1
(prior art)

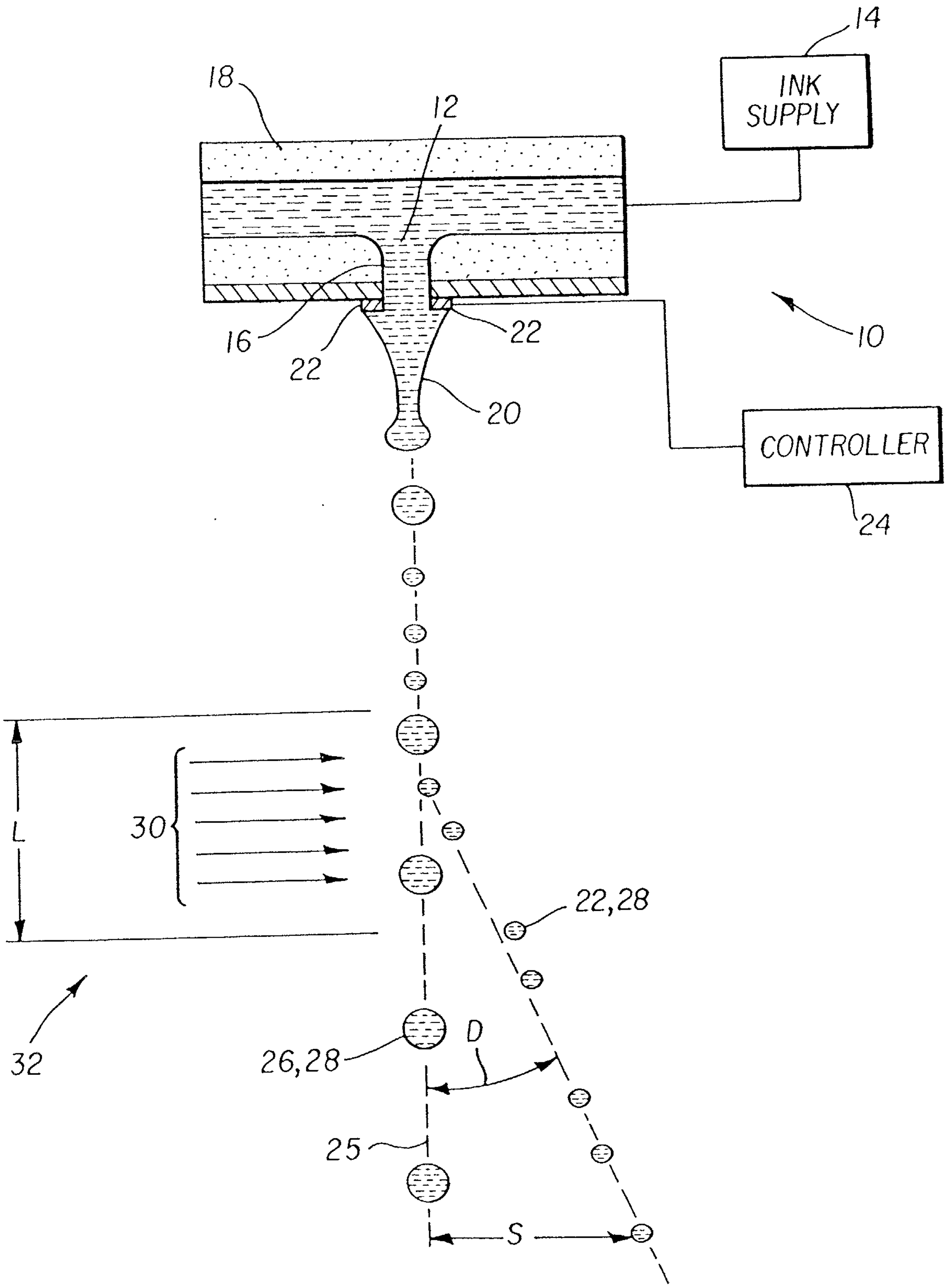
14
INK SUPPLY
18
12
10
16
22
22
20
CONTROLLER
24
L
30
22,28
32
D
26,28
25
S

FIG. 2a

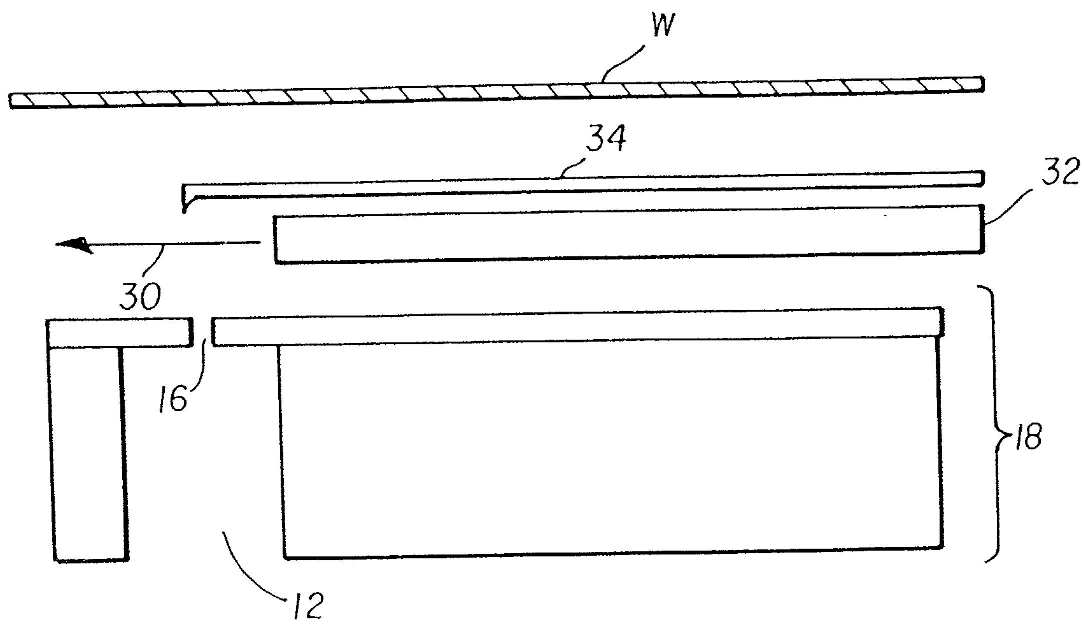
W
34
32
30
16
18
12

FIG. 2b

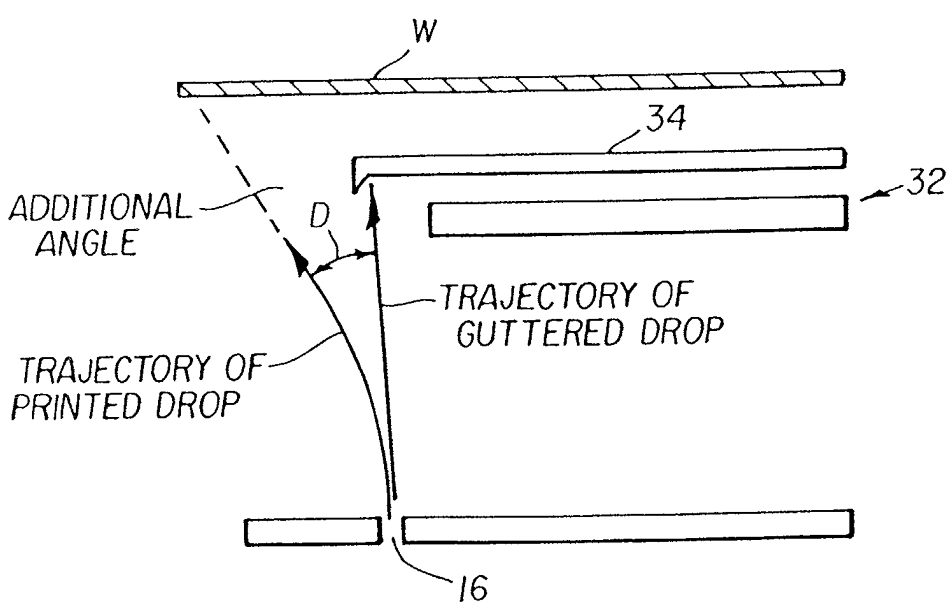
W
34
32
ADDITIONAL ANGLE
D
TRAJECTORY OF GUTTERED DROP
TRAJECTORY OF PRINTED DROP
16

FIG. 2c

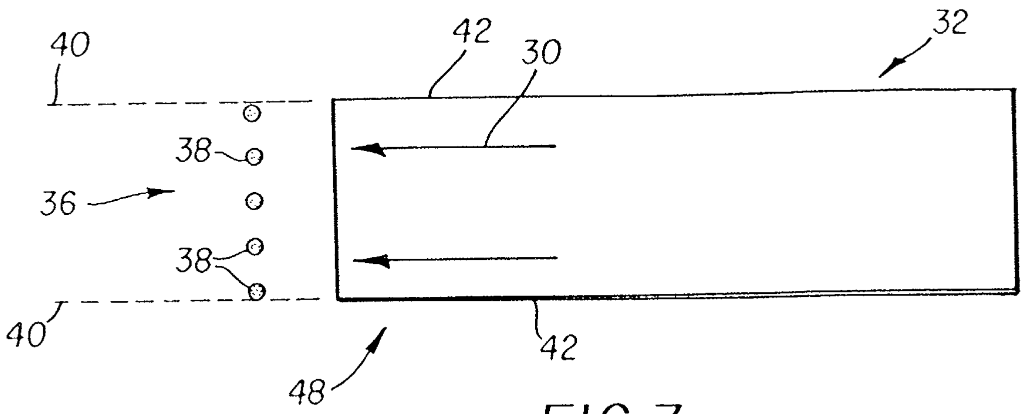

FIG. 3a

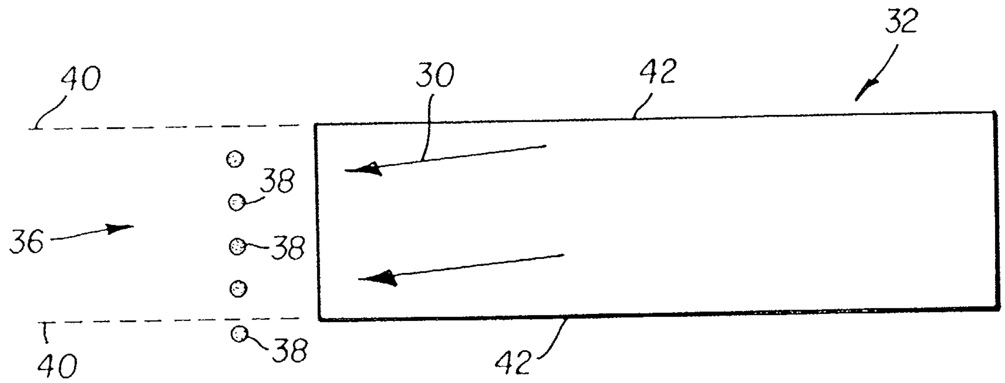

FIG. 3b

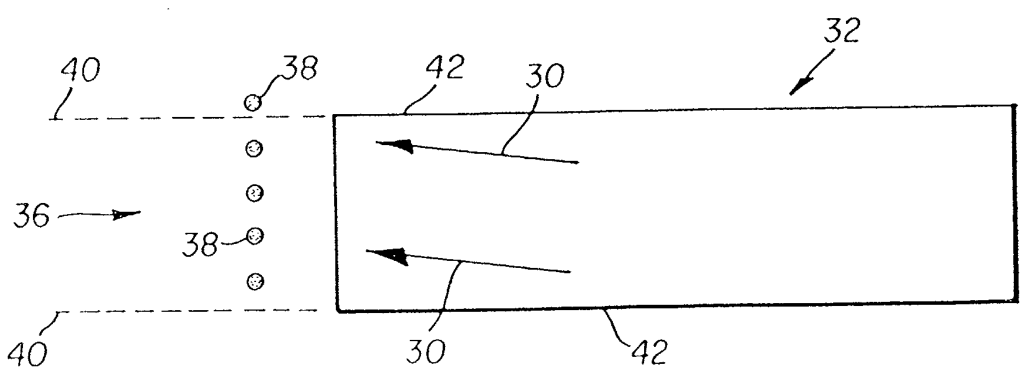

FIG. 3c

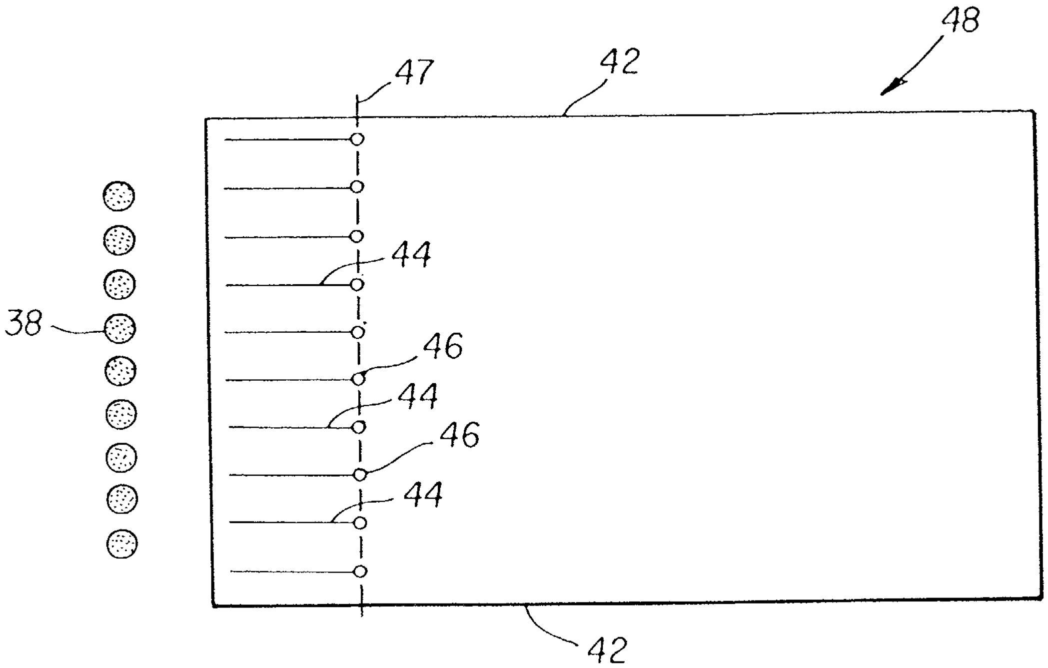

FIG. 4a

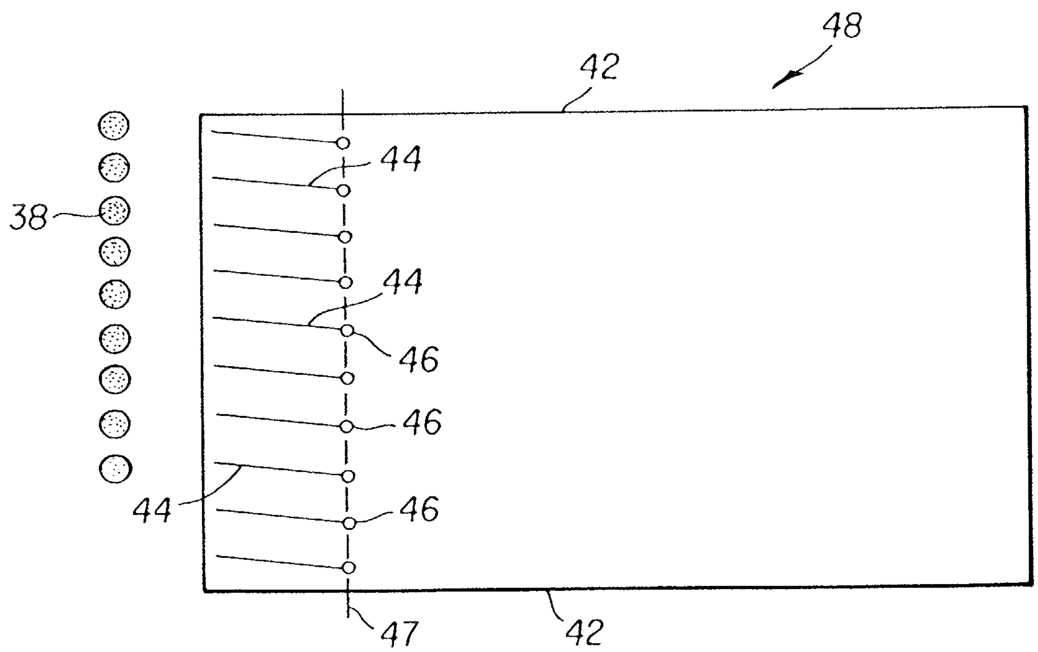

FIG. 4b

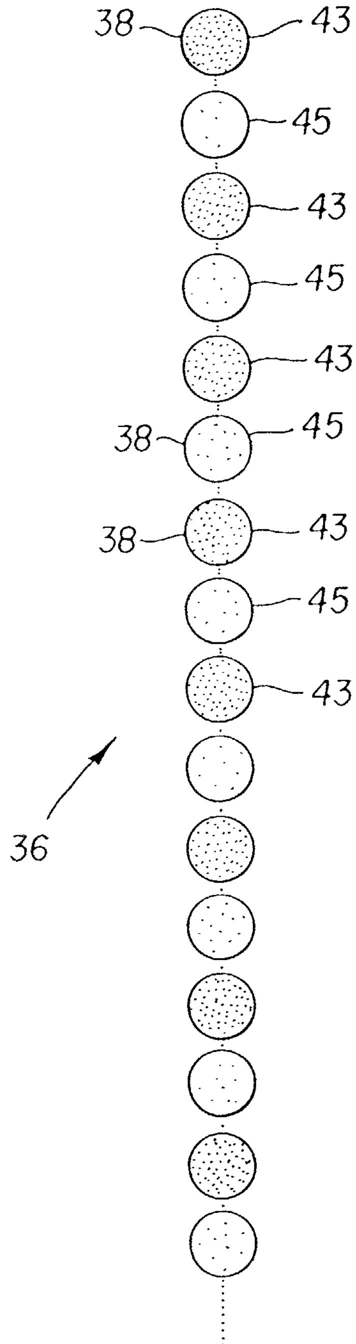

FIG. 4c

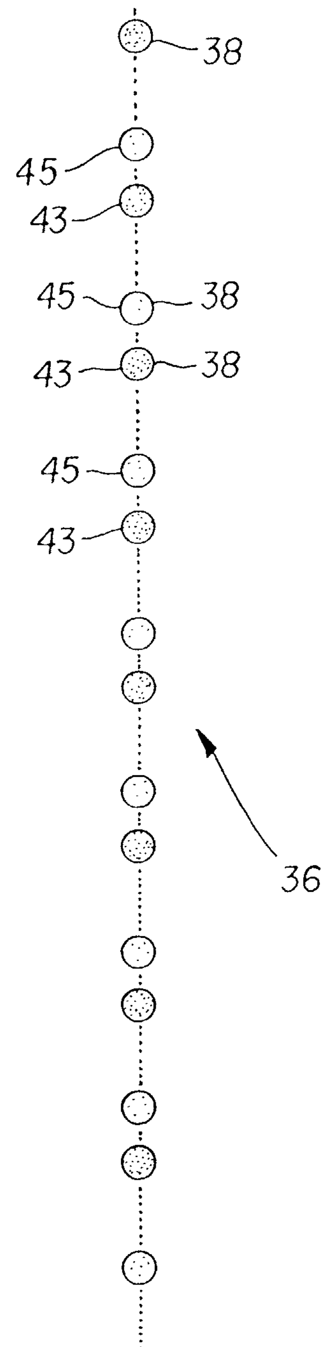

FIG. 4d

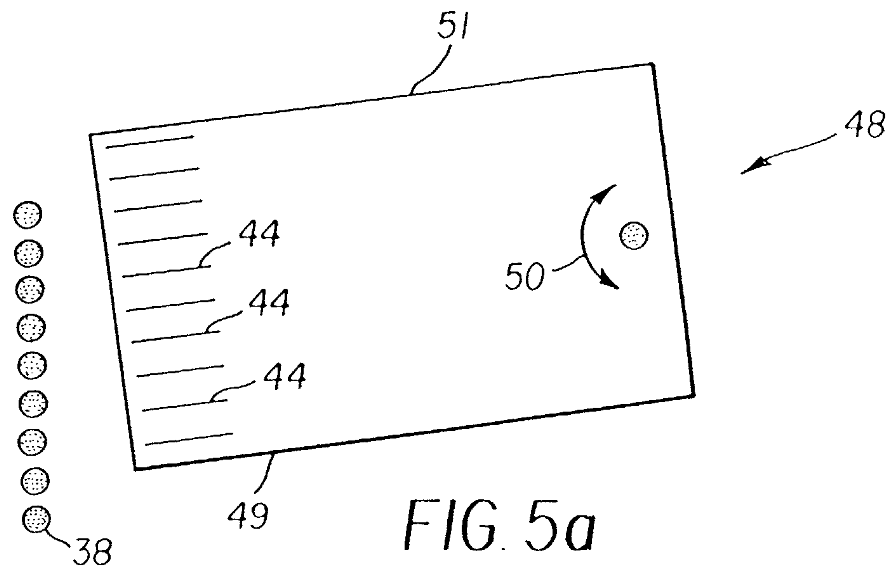

FIG. 5a

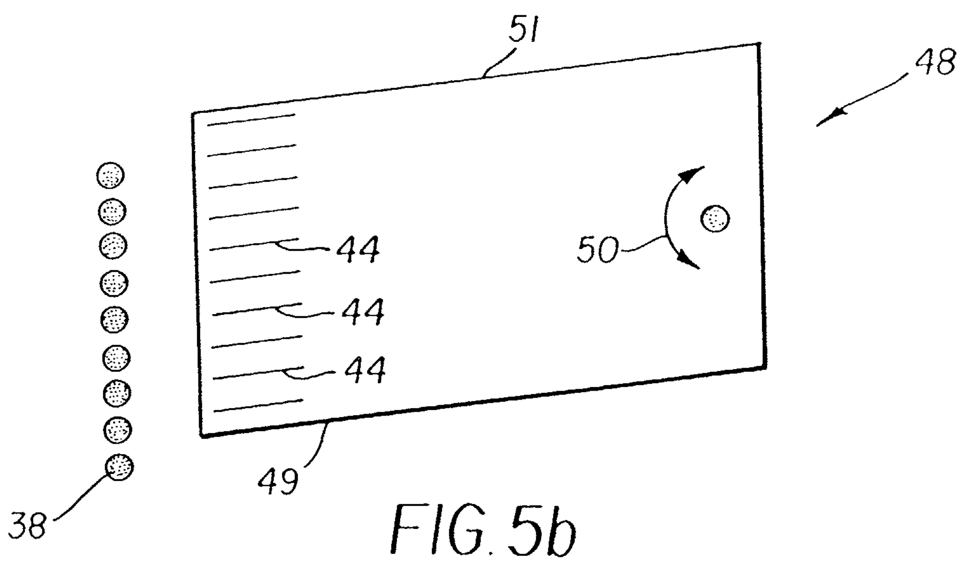

FIG. 5b

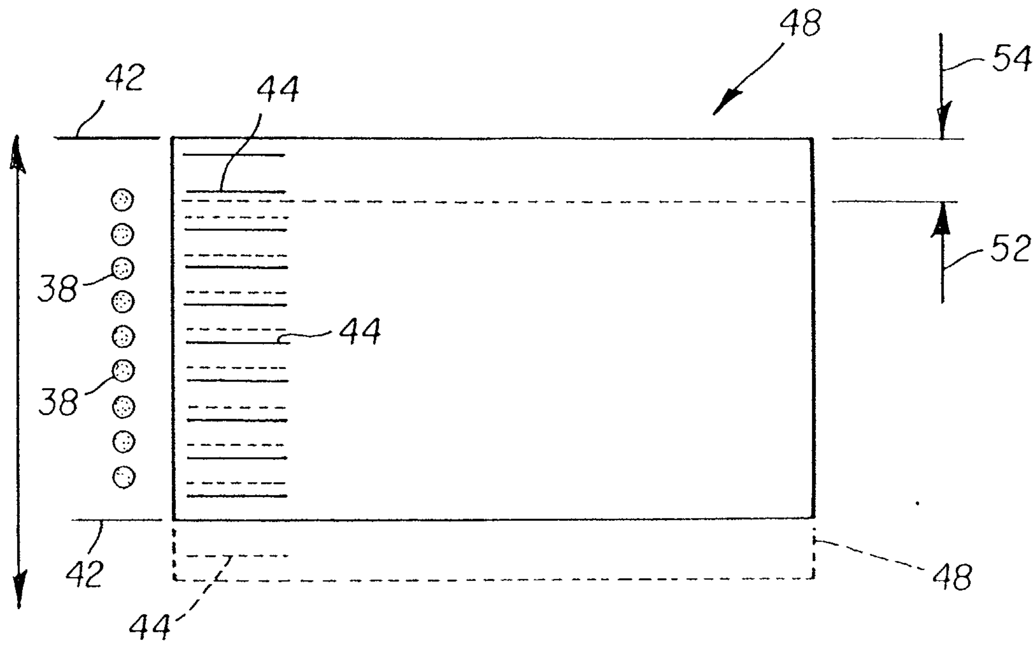
48
42
44
54
52
38
44
38
42
48
44

FIG. 6a

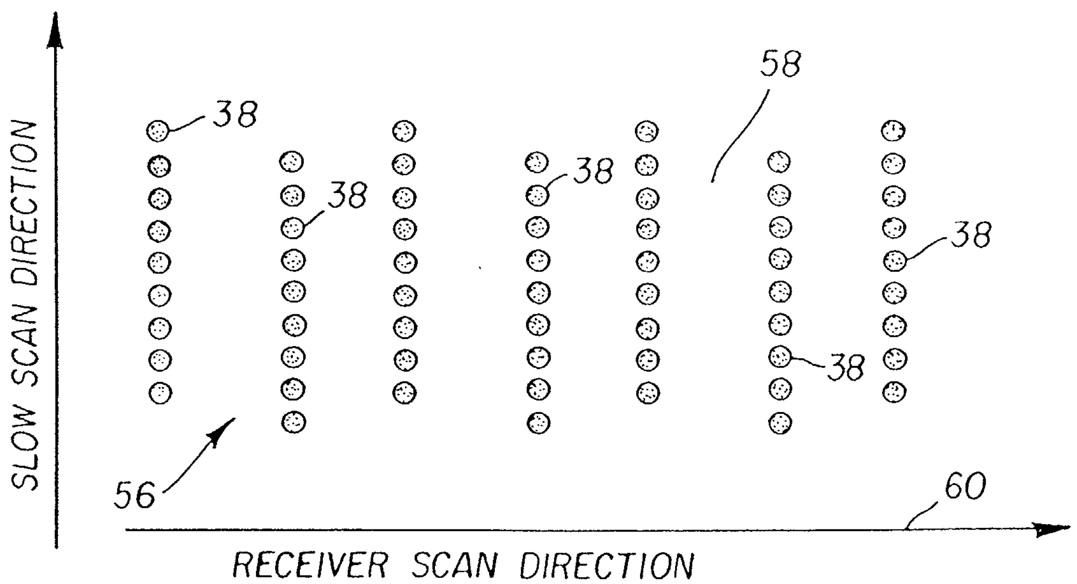
58
38
38
38
38
38
SLOW SCAN DIRECTION
56
60
RECEIVER SCAN DIRECTION

FIG. 6b

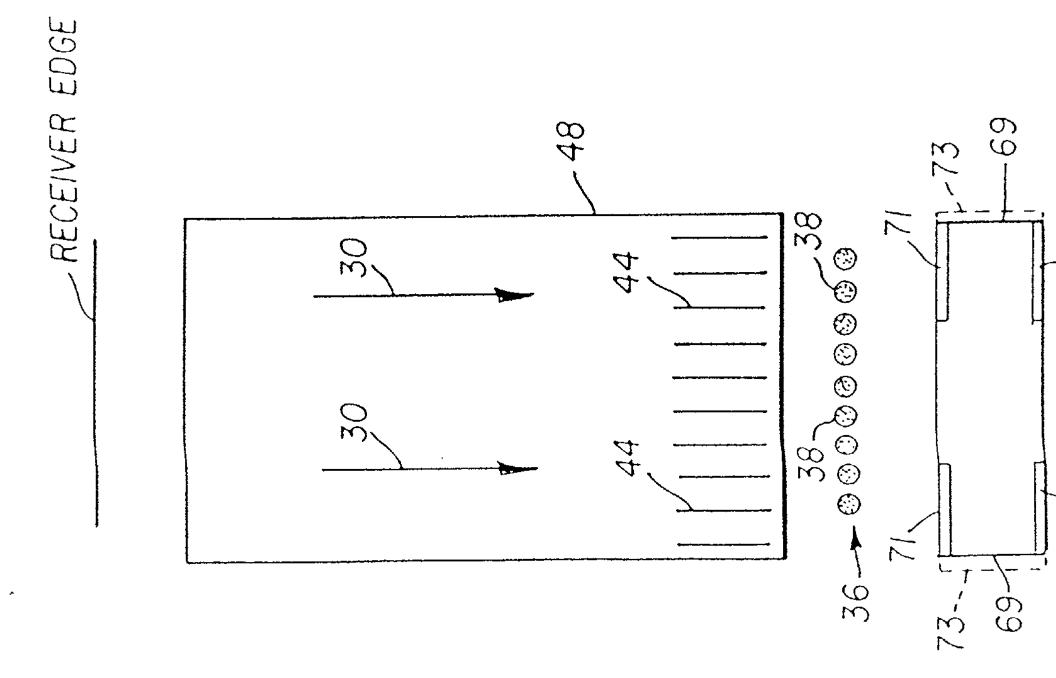
RECEIVER EDGE
48
30
30
44
44
38
38
36
71
71
71
71
73
73
69
69
64

FIG. 7a

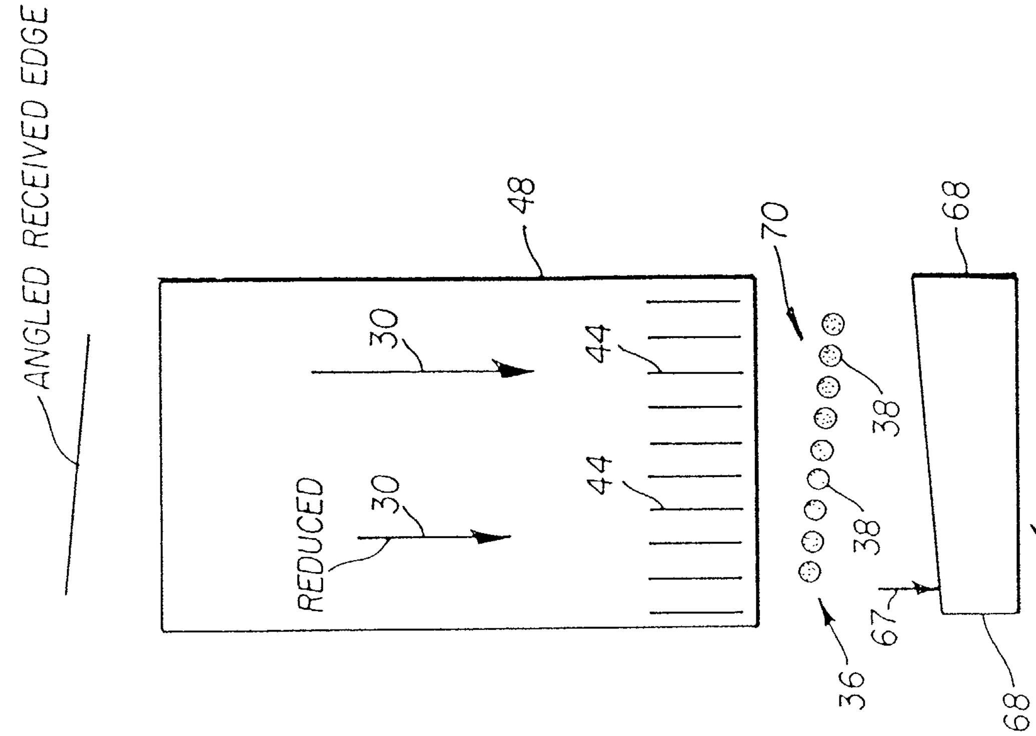
ANGLED RECEIVED EDGE
REDUCED
48
30
30
44
44
70
38
38
36
67
68
68
66

FIG. 7b

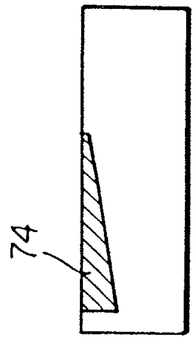

FIG. 7e

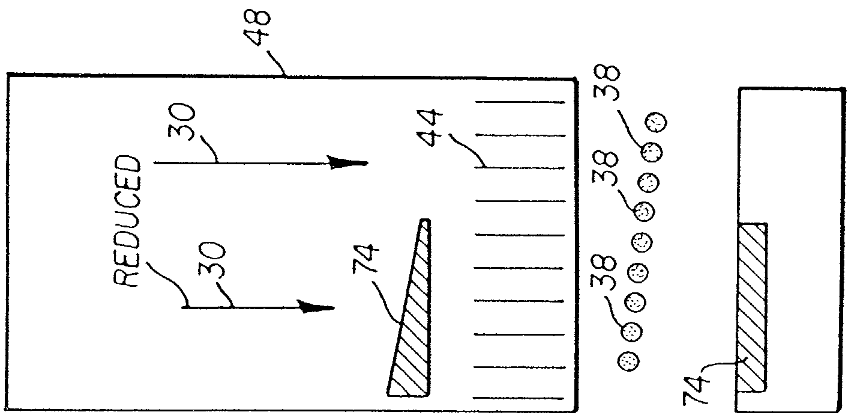

FIG. 7d

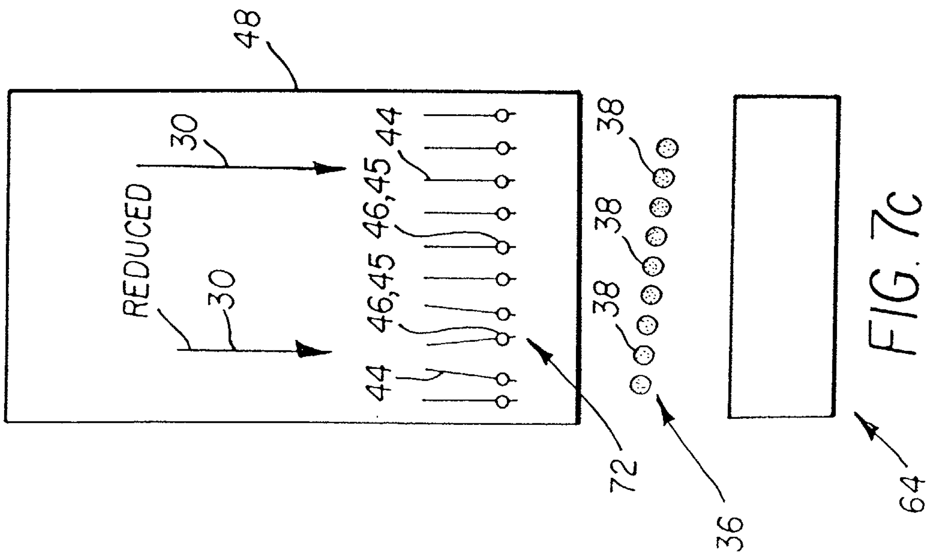

FIG. 7c

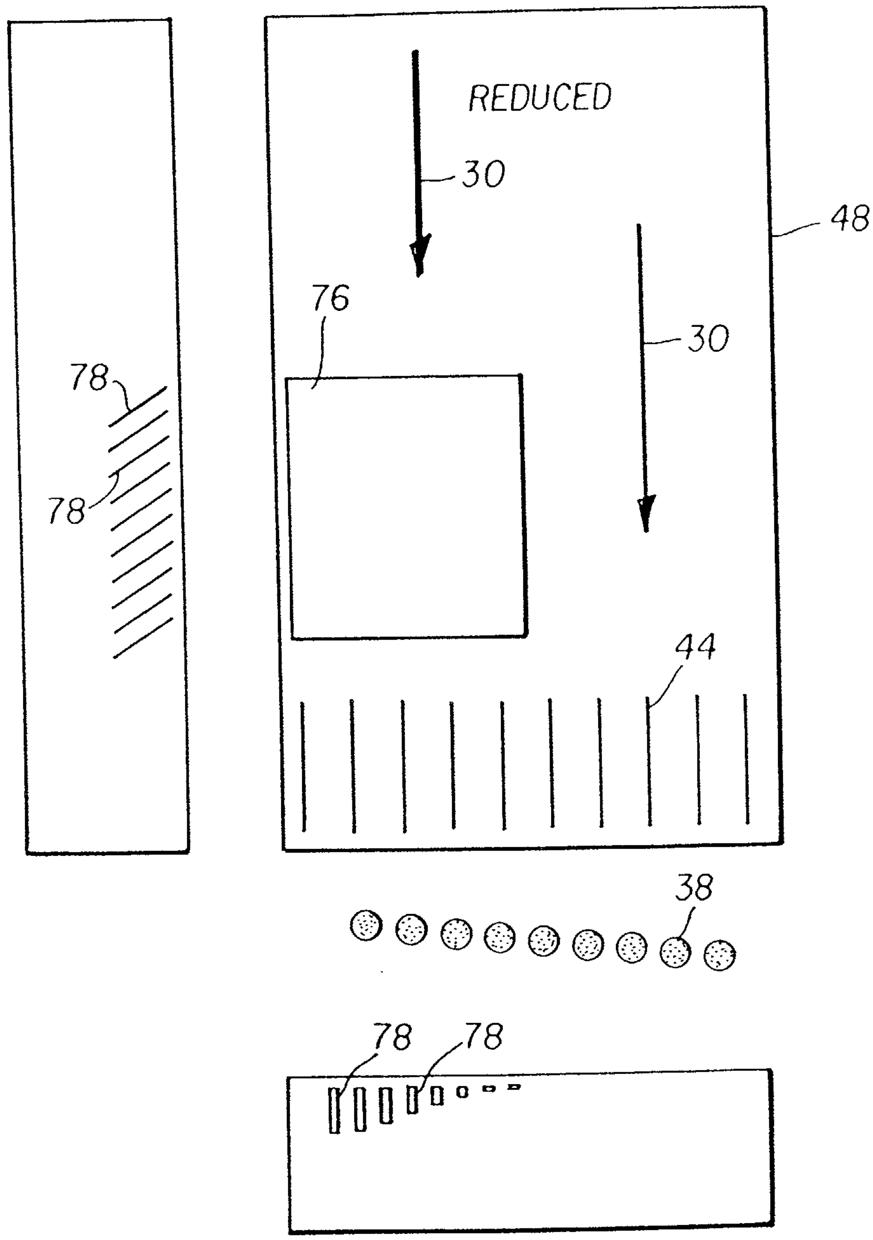

FIG. 7f

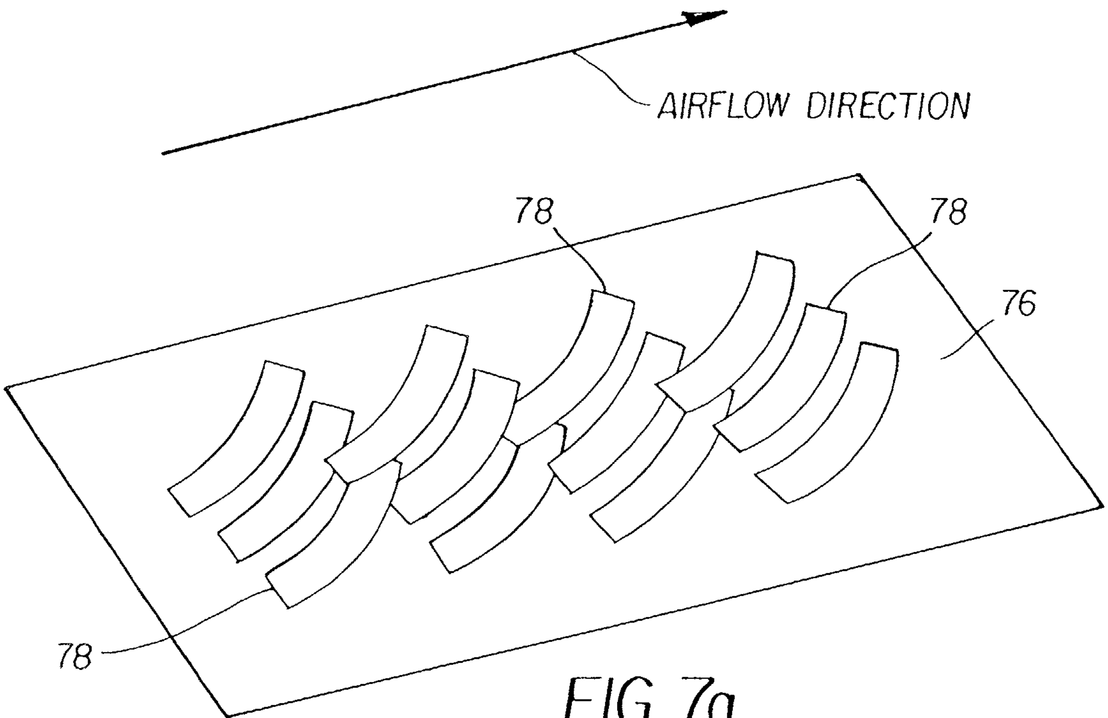

FIG. 7g